

**POLYAMINES AND ANTI-DIARRHEAL AND
GASTROINTESTINAL ANTI-SPASMODIC
PHARMACEUTICAL COMPOSITIONS AND
METHODS OF TREATMENT**

RELATED APPLICATIONS

This is a continuation-in-part of application Ser. No. 07/870,441, filed Oct. 9, 1991, now abandoned, which is a continuation-in-part of application Ser. No. 07/210,520, filed Jun. 23, 1988, now U.S. Pat. No. 5,091,576, which is a continuation-in-part of application Ser. No. 07/066,227, filed Jun. 25, 1987, now abandoned, which was a continuation-in-part of application Ser. No. 06/936,835, filed Dec. 2, 1986, now abandoned.

BACKGROUND OF THE INVENTION

This invention was made with United States Government support under Grant NCDDG-CA37606, awarded by the National Cancer Institute. The United States Government has certain rights in this invention.

The present invention relates to certain novel anti-diarrheal and gastrointestinal anti-spasmodic agents and methods of treatment and pharmaceutical compositions based thereon.

DESCRIPTION OF THE PRIOR ART

Diarrhea can result from a variety of pathophysiological disorders including bacterial and parasitic infections, disease or debilitation of organs such as liver, adrenal and others. It can also occur as a result of other therapy or diet. In all cases, diarrhea is generally a symptom of organic gastrointestinal disorders and not itself a disorder. Chronic diarrhea is generally due to: (1) hypersecretion of fluid and electrolytes of the stomach, small intestine and colon; (2) inability to absorb certain nutrients (malabsorption); and (3) intestinal hypermotility and rapid transport. These may occur separately or in combination. Certain disorders may have diarrhea as a prominent feature of the disease/syndrome, but the specific etiology is unclear. In this latter group, emotional tension and psychological factors may adversely influence the frequency of the symptoms.

Diarrhea and diarrheal diseases are one of the most frequent causes of morbidity and mortality, especially in less developed countries wherein the number of those killed by such diseases is estimated at about 5 million persons per annum. Particularly dangerous are diarrheal diseases of the newborn and the youngest group of babies (S. Hughes: *Drugs*, Vol. 26, pp. 80-90 (1983)).

In mechanized or automated large capacity farms, diarrhea and infections of the respiratory tract are frequent, especially with young livestock and the high mortality or growth deceleration thereof have a considerable negative economical effect. Diarrheal diseases of man and animals are caused by a plurality of etiological factors, especially of microbial and viral character. The most prevalent microbes are gram-negative bacteria, *Escherichia coli* and *Vibrio cholerae*. However, it is now clear that other bacteria, viruses and parasites (protozoan, amoeba, etc.) also cause severe problems.

Diarrheal diseases are treated by rehydration therapy using preparations composed of various salts (potassium chloride, sodium chloride, sodium hydrogen carbonate) and glucose, whereby quick compensation for the loss of water and ions, as well as for acidosis, occurs. However, the occurrence of diarrheal diseases is not influ-

enced. Other substances of the same kind produce similar results.

Anti-diarrheal compounds are, of course, well known in the medicinal arts and take various forms. In particular, there are a variety of products known which act systemically to provide anti-diarrheal effects when administered in a manner which will enable the drug to be taken into the system at effective therapeutic levels.

In addition, there are anti-cholinergic substances applied together with spasmolytics such as Reasec® (Janssen) which contain diphenyloxylate and atropin. Both human and veterinary medicine use chemotherapeutic agents with anti-bacterial effects, such as sulfonamides, or antibiotics are availed of which are apt to suppress certain infections.

Medicaments are also aimed at the sphere of regulation depending on receptors, especially those localized on the basolateral membrane, further by means of an intracellular mechanism of intervention by the so-called secondary messenger, and by influencing the transport mechanism, especially boundary membranes. The modulation of receptor-dependent regulation mechanisms can be influenced, to some extent, by medicaments of the type α_2 adrenergic agonists such as clonidine (Catapresan®) (E. B. Chang et al, *Gastroenterology*, Vol. 91, pp. 564-569 (1986)), somatostatin, or enkephalin and morphine analogs. For influencing the transport of ions through the membrane, it is also possible to use α_2 adrenergic agonists (E. B. Chang et al, *Am. J. Physiol.*, Vol. 1982, p. 242). Reference has also been made to the use of lidamidine, i.e., the medicament having a damping effect on the intestine peristaltics (M. D. Dharmasathphorn: *Gastroenterology*, Vol. 91, pp. 769-775 (1986)).

Disadvantages of anti-diarrheal medicaments, i.e., those referred to in professional papers rather than those medicaments of this type applied in practice, include their secondary strong effects such as anti-hypertensive effects (clonidine), growth factors (somatostatin), habituation and/or incomplete pre-clinical research (enkephalin derivatives). The application of large doses of antibiotics and long administration thereof has not proved optimum in epidemical diarrhea localities. Where the diarrhea inducing agent is cholera toxin, however, there does not exist any efficient protection, except for inoculum which is not sufficiently patent either, and gives short term protection only (3 months) and low efficiency (30-40%).

In recent years, a great deal of attention has been focussed on the polyamines, e.g., spermidine, norspermidine, homospermidine, 1,4-diaminobutane (putrescine) and spermine. These studies have been largely directed at the biological properties of the polyamines probably because of the role they play in proliferative processes. It was shown early on that the polyamine levels in dividing cells, e.g., cancer cells, are much higher than in resting cells. See Janne et al, *A. Biochim. Biophys. Acta.*, Vol. 473, p. 241 (1978); Fillingame et al, *Proc. Natl. Acad. Sci. U.S.A.*, Vol. 72, p. 4042 (1975); Metcalf et al, *J. Am. Chem. Soc.*, Vol. 100, p. 2551 (1978); Flink et al, *Nature (London)*, Vol. 253, p. 62 (1975); and Pegg et al, *Polyamine Metabolism and Function*, *Am. J. Cell. Physiol.*, Vol. 243, pp. 212-221 (1982).

Several lines of evidence indicate that polyamines, particularly spermidine, are required for cell proliferation: (i) they are found in greater amounts in growing than in non-growing tissues; (ii) prokaryotic and eukar-

veterinary and human use, comprise the agent together with one or more acceptable carriers therefor and optionally other therapeutic ingredients. The carrier(s) must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not deleterious to the recipient thereof. Desirably, the formulations should not include oxidizing agents and other substances with which the agents are known to be incompatible. The formulations may conveniently be presented in unit dosage form and may be prepared by any of the methods well known in the art of pharmacy. All methods include the step of bringing into association the agent with the carrier which constitutes one or more accessory ingredients. In general, the formulations are prepared by uniformly and intimately bringing into association the agent with the carrier(s) and then, if necessary, dividing the product into unit dosages thereof.

Formulations suitable for parenteral administration conveniently comprise sterile aqueous preparations of the agents which are preferably isotonic with the blood of the recipient. Suitable such carrier solutions include phosphate buffered saline, saline, water, lactated ringers or dextrose (5% in water). Such formulations may be conveniently prepared by admixing the agent with water to produce a solution or suspension which is filled into a sterile container and sealed against bacterial contamination. Preferably, sterile materials are used under aseptic manufacturing conditions to avoid the need for terminal sterilization.

Such formulations may optionally contain one or more additional ingredients among which may be mentioned preservatives, such as methyl hydroxybenzoate, chlorocresol, metacresol, phenol and benzalkonium chloride. Such materials are of special value when the formulations are presented in multi-dose containers.

Buffers may also be included to provide a suitable pH value for the formulation and suitable materials include sodium phosphate and acetate. Sodium chloride or glycerin may be used to render a formulation isotonic with the blood. If desired, the formulation may be filled into the containers under an inert atmosphere such as nitrogen or may contain an anti-oxidant and are conveniently presented in unit dose or multi-dose form, for example, in a sealed ampoule.

It will be appreciated that while the agents described herein form acid addition salts and carboxyl acid salts, the biological activity thereof will reside in the agent itself. These salts may be used in human and in veterinary medicine and presented as pharmaceutical formulations in the manner and in the amounts (calculated as the base) described hereinabove, and it is then preferable that the acid moiety be pharmacologically and pharmaceutically acceptable to the recipient. Examples of such suitable acids include (a) mineral acids: hydrochloric, hydrobromic, phosphoric, metaphosphoric, and sulfuric acids; (b) organic acids: tartaric, acetic, citric, malic, lactic, fumaric, benzoic, glycollic, gluconic, gluconic, succinic and arylsulfonic, for example, p-toluene-sulfonic acids.

In compounds of the invention, R₁ and R₆ are preferably methyl, ethyl, propyl, benzyl, etc., it being understood that the term "aralkyl" is intended to embrace any aromatic group, the chemical and physical properties of which do not adversely affect the efficacy and safety of the compound for therapeutic applications. Preferred, however, are the hydrocarbyl aralkyl groups, i.e., comprised only of C and H atoms.

R₂-R₅ preferably are H, methyl, ethyl, propyl or benzyl.

Compounds of the above formulae are synthesized according to the methods described in application Ser. No. 07/210,520 filed Jun. 23, 1988, now U.S. Pat. No. 5,091,576, and Ser. No. 07/870,441 filed Oct. 9, 1991, the entire contents and disclosures of both of which are incorporated herein by reference.

Although, as noted above, it has been reported that diethylhomospermine (DEHSPM) inhibits gastrointestinal motility in rats, it has been determined that this inhibition is extremely dependent on structural motifs within the molecule. Preliminary receptor binding experiments suggest that DEHSPM is not a classic anticholinergic or anti-adrenergic.

The invention is illustrated by the following non-limiting examples.

EXAMPLE 1

This study represents an attempt to elucidate a possible mechanism(s) for the above-noted observed inhibition of gastrointestinal motility in rats. The phasic and sustained contractions of guinea pig taenia coli were determined in a perfused organ bath apparatus. DEHSPM (0.1 mM, 0.5 mM and 1.0 mM) progressively inhibited spontaneous phasic contractions by a TTX-insensitive mechanism. TTX (1.0-20.0 μM) blocked field stimulation-induced contractions without altering the DEHSPM attenuation of phasic contractions:

Treatment	Phasic Contract/20 min.	Amplitude/20 min.
Baseline	5.8 ± 0.4	4.8 ± 0.3
DEHSPM (1.0 mM)	2.3 ± 0.5***	2.2 ± 0.4***

***p < 0.0001 compared to baseline. Data expressed as mean ± SEM.

In an attempt to support the above bethanechol experiments, increasing cumulative concentrations of carbachol (1.0 nM to 1.0 μM half-log changes) were used alone and following DEHSPM (1.0 mM). Only the highest concentration (1.0 μM) of carbachol was able to overcome the inhibitory effects of DEHSPM. Interestingly, the majority of the tissues tested (>80%) were of the phasic contractile type. In order to consistently test the sustained contractions, 20 mM KCl was used to induce a sustained contraction. Similar to the phasic tissues, DEHSPM (1.0 mM) significantly inhibited the KCl-induced contraction. Results are expressed as the extent of relaxation (%) and as compared to nitroprusside (1.0 mM), a classic relaxation agent:

Treatment	% Relaxation	% Nipride Relaxation
DEHSPM (1.0 mM)	81 ± 11	240
DEHSPM (0.5 mM)	33 ± 4	129
DEHSPM (0.1 mM)	5 ± 2	16

Both the nitric oxide synthase inhibitor, L-NAME (20 mM), and methylene blue (10 μM) partially blocked the inhibition caused by DEHSPM. Hemoglobin-containing compounds partially block DEHSPM-induced inhibition of phasic contractions and relaxation of KCl-induced contractions. It can be deduced, therefore, from the above results that the profound inhibition caused by DEHSPM in isolated GI tissues is due, in part, to a nitric oxide mechanism. DEHSPM apparently causes relaxation either through a direct myogenic in-

teraction or through an Na-independent neural pathway.

EXAMPLE 2

To test the hypothesis that DEHSPM would cause alterations of myoelectric activity and transit of the small intestine similar to those noted with the use of isoproterchol (ISO), myoelectric activity was monitored in rats during fasting by four in-dwelling electrodes. Intestinal transit was measured by the movement of radiochromium, expressed as the geometric center. Intestinal myoelectric activity and transit were determined after a single s.c. injection of saline or 5 mg/kg DEHSPM. In addition, myoelectric activity was monitored after chronic administration of 5 mg/kg bid for 6 days. The interval between activity fronts (AF) of the migrating myoelectric complex (MMC), propagation velocity of the AF and the duration of spike inhibition (min.) after each injection are reported below:

		AF Interval	AF Propagation Velocity	Inhibition	Geo. Ctr.
Baseline		10.8 ± 1.0	3.0 ± 0.5	—	4.0 ± 0.5
Single	Day 1	22.6 ± 1.6*	1.3 ± 0.1*	44.5 ± 3.2*	1.3 ± 0.2*
	Day 4	14.7 ± 2.4	1.5 ± 0.1*	—	—
Chronic	Day 5	40.3 ± 8.9*	1.8 ± 0.3	—	—

Mean ± SEM in minutes.

*p 0.05 propagation velocity = cm/min.

In summary, therefore, it can be stated, based on the above evidence, that (1) DEHSPM causes significant inhibition of small intestinal myoelectric activity; (2) DEHSPM significantly delays transit of small intestine; and (3) chronic administration of DEHSPM induces profound alterations of intestinal motility.

These findings with DEHSPM are similar to those reported after administration of ISO, but DEHSPM-induced alterations have a much longer duration. It is hypothesized that polyamines may interact non-covalently with specific biochemical macromolecules or a second messenger system responsible for the maintenance of intestinal motility. Furthermore, the gastrointestinal toxicity observed with DEHSPM appears to be related to alterations of intestinal motility.

EXAMPLE 3

Further studies were conducted to determine the effect of DEHSPM on gastric emptying and selected pharmacologic agents were used to determine the mechanism of action. A radiochromium method was used to measure the % gastric emptying (GE) and intestinal transit expressed as geometric center (GC). Percent GE, % reversal in GE from DEHSPM treatment and GC were determined after a single dose of DEHSPM and the respective pharmacologic agent with the following results:

Treatment (mg/kg Route)	% GE	% Reversal	GC
Saline Control	82.5 ± 3.0	100.0	5.1 ± 0.3
DEHSPM (5 sc) + Saline	14.3 ± 4.2	—	1.5 ± 0.2
Metoclopramide (5 ip)	27.4 ± 2.3	19.6*	1.6 ± 0.1
Verapamil (5 ip)	45.4 ± 2.8	45.2***	2.3 ± 0.1**
Propranolol (5 sc)	44.7 ± 5.3	44.2**	1.9 ± 0.2
Yohimbine (1 sc)	31.3 ± 5.7	24.4	2.1 ± 0.2
Naloxone (1 sc)	34.4 ± 6.5	29.2	2.2 ± 0.2
Bethanechol (0.05 ip)	44.8 ± 8.2	44.3**	2.2 ± 0.1

-continued

Treatment (mg/kg Route)	% GE	% Reversal	GC
(0.5 ip)	85.2 ± 2.8	103.0***	3.6 ± 0.2***
(10.0 ip)	94.9 ± 0.9	117.2***	6.4 ± 0.3***

Mean ± SEM. p values: <0.05, **<0.02, ***<0.0002

In summary, (1) DEHSPM significantly delayed GE and small intestinal transit; (2) DEHSPM's inhibition of GE was only partially but significantly reversed by dopaminergic, calcium channel, and β -adrenergic antagonists. In contrast, bethanechol completely reversed DEHSPM's effect. (3) DEHSPM's inhibition of intestinal transit was improved significantly by a calcium channel antagonist and a cholinergic agonist.

These data suggest that calcium mobilization and the β -adrenergic system are intimately involved in DEHSPM's effect on motility. This is probably not an atropine-like effect because atropine does not inhibit

motility in rats. It can be postulated that bethanechol may provide an important adjunct to chemotherapeutic regimes containing analogs of the polyamine pathway.

EXAMPLE 4

The activity of DEHSPM as a potent anti-diarrheal agent was tested in a castor oil-induced diarrhea model in rats. Fasted rats were injected s.c. with saline or DEHSPM at 0.2, 1.0 or 5.0 mg/kg and had orogastric gavage of 2 ml of castor oil. Time of first diarrheal stool (min.) and weight (wt.) loss at 2, 4 and 6 hours were measured. The results are expressed below as mean ± SEM.

	1st Stool	2 Hour Wt. Loss	4 Hour Wt. Loss	6 Hour Wt. Loss
Saline	104 ± 30	4.1 ± 0.9	7.2 ± 1.2	9.1 ± 1.1
0.2 mg/kg	261 ± 40*	1.6 ± 0.4*	3.8 ± 0.6*	5.2 ± 0.7*
1.0 mg/kg	>360**	0.7 ± 0.3**	2.0 ± 0.3**	2.5 ± 0.4**
5.0 mg/kg	>360**	1.1 ± 0.3**	1.9 ± 0.3**	2.6 ± 0.4**

*p < 0.02 and **p < 0.001 compared to saline + castor oil

Interestingly, L-NAME, a nitric oxide synthase inhibitor, is reported to prevent diarrhea in this animal model and it can be reversed with L-arginine. DEHSPM may interact with oxygen radicals because it has potent cyto-protective effects against alcohol-induced gastritis. Therefore, it was hypothesized that L-arginine may reverse DEHSPM's anti-diarrheal effect. L-arginine, 600 mg/kg i.p., failed to alter DEHSPM's beneficial effects in this model. In summary, then, DEHSPM is a potent anti-diarrheal agent that profoundly inhibits motility. The possibility cannot be excluded that DEHSPM may also have anti-secretory activity because the lowest dose that was effective

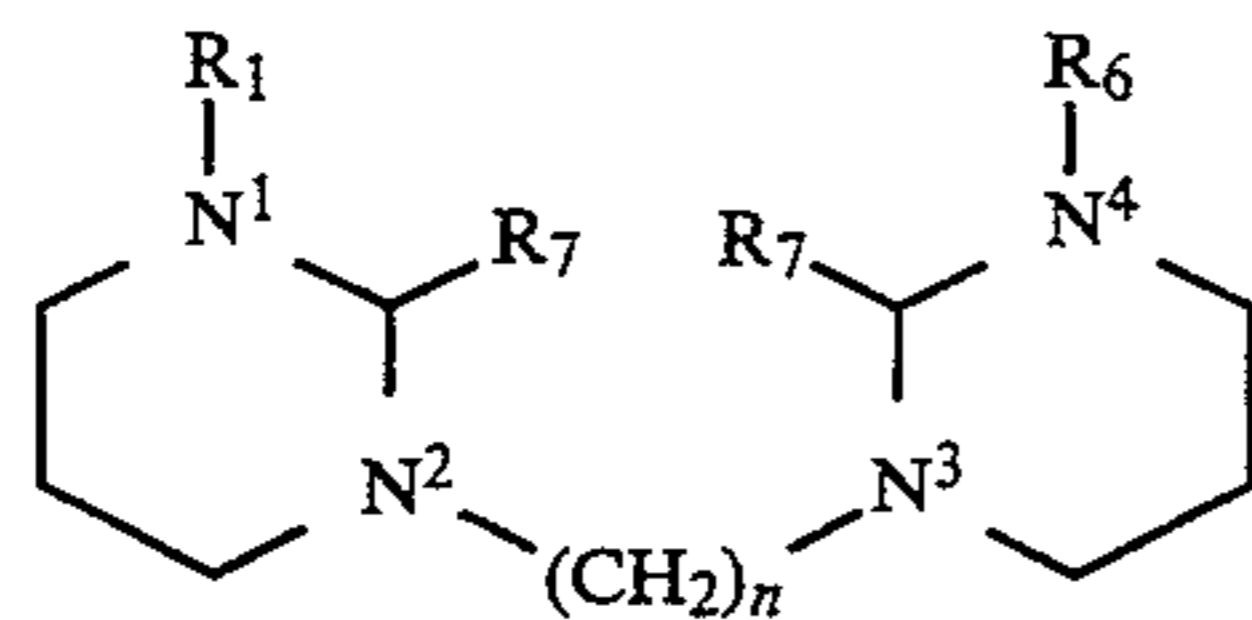
in this diarrheal model has only limited anti-transit effects.

EXAMPLE 5

The mechanism by which DEHSPM inhibits diarrhea was further studied by investigating the effects of the compound on cholera-induced secretion in the ligated intestinal loop model in rats. In this model, the rats were anesthetized and isolated intestinal loops were separated and 10 μ g of cholera toxin was injected along with a small amount of saline. DEHSPM caused a significant reduction in the amount of accumulated fluid in jejunal segments and a trend to decrease fluid acceleration in the ileum. This effect was dose-related and occurred at 0.2 mg/kg s.c., but its enhanced absorption was more marked at the 1 and 5 mg/kg dose. The results from those doses compared favorably to the response observed with large doses of clonidine, in α_2 -adrenergic agonist used in reference compound.

We claim:

1. An anti-diarrheal or gastrointestinal anti-spasmodic pharmaceutical composition comprising an effective amount of a compound having the formula:



wherein:

R_1 and R_6 may be the same or different and are H, alkyl or aralkyl having from 1 to 12 carbon atoms; R_7 is H, alkyl, aryl or aralkyl having from 1 to 12 carbon atoms;

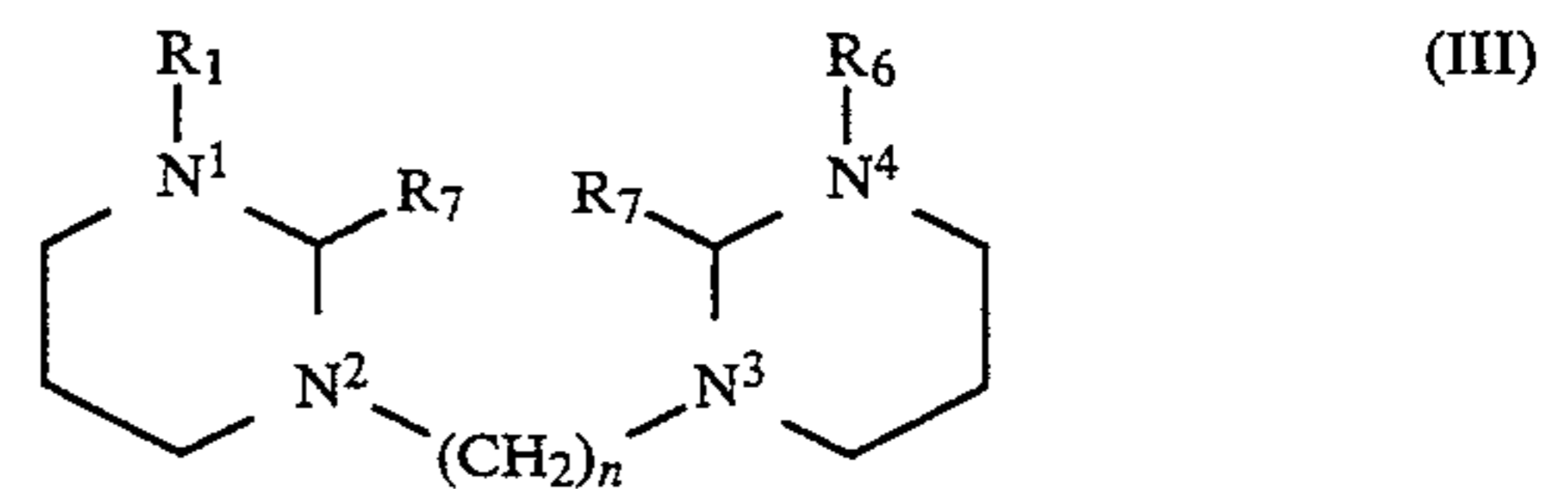
n is an integer from 3 to 6, inclusive; or (IV) a salt thereof with a pharmaceutically acceptable acid; and a pharmaceutically acceptable carrier therefor.

2. A composition according to claim 1 wherein at least two of said R_1 , R_6 and R_7 groups are t-butyl.

3. A composition according to claim 1 wherein said compound has the formula (III) and n is 3.

4. A composition according to claim 1 wherein said compound has the formula (III) and n is 4.

5. A method of treating diarrhea or gastrointestinal spasm in a human or non-human animal in need thereof comprising administering to said animal an effective amount of a compound having the formula:



wherein:

R_1 and R_6 may be the same or different and are H, alkyl or aralkyl having from 1 to 12 carbon atoms; R_7 is H, alkyl, aryl or aralkyl having from 1 to 12 carbon atoms;

n is an integer from 3 to 6, inclusive; or

(IV) a salt thereof with a pharmaceutically acceptable acid.

6. A method according to claim 5 wherein at least two of said R_1 , R_6 and R_7 groups are t-butyl.

7. A method according to claim 5 wherein said compound is of formula (III) and wherein n is 3.

8. A method according to claim 5 wherein said compound is of formula (III) and wherein n is 4.

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